Environmental and Cost Synergy in Supply Chain Network Integration in Mergers and Acquisitions

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Contributions

- We focus on the case of horizontal mergers (or acquisitions) and extend the contributions in Nagurney (2008) to include multicriteria decision-making and environmental concerns.

- We analyze the synergy effects associated with a merger, in terms of the operational synergy, that is, the reduction, if any, in the cost of production, storage, and distribution, as well as the environmental benefits in terms of the reduction of associated emissions (if any).

- The framework is based on a supply chain network perspective, in a system-optimization context.

- Numerical Examples

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Customer and Competitive Pressures

- Customers and suppliers will punish polluters in the marketplace that violate environmental rules. Polluters may face lower profits, also called a "reputational penalty," which will be manifested in a lower stock price for the company (Klein and Leffler (1981), Klassen and McLaughlin (1996)).
  - Roper Starch Worldwide (1997) noted that more than 75% of the public will switch to a brand associated with the environment when price and quality are equal.
  - Nearly 60% percent of the public favors organizations that support the environment (Roper Starch Worldwide (1997)).
- Firms in the public eye have not only met, but exceeded, the required environmental mandates (Lyon (2003)).
  - In the U.S., over 1,200 firms voluntarily participated in the EPA's 33/50 program, agreeing to reduce certain chemical emissions 50% by 1995 (Arora and Cason (1996)).

Green Supply Chain Management

- "The real competition is not company against company but supply chain against supply chain" (Albino, Izzo, and Uhtz (2002)).
- Reputation: Accountable for not only own performance, but also that of their suppliers, subcontractors, and distribution outlets.
- In 2005, Wal-Mart vowed to buy 100% of its electricity from renewable resources, produce no waste, double the fuel efficiency of its trucks and reduce GHG emissions by 20%. It also said it expected its 60,000 suppliers worldwide to follow its lead if they wanted to continue doing business with Wal-Mart. -usinfo.state.gov

Firms and the Environment

- Firms are increasingly realizing the importance of their environmental impacts and the return on the bottom line for those actions expended to reduce pollution (Hart and Ahuja (1996)).
  - 3M saved almost $500 million by implementing over 3000 projects that have reduced emissions by over 1 billion pounds since 1975 (Walley and Whitehead (1994)).
  - DuPont has the equivalent of 35% of its share price invested in capital and operating expenditures related to protecting the environment. A 15% improvement in efficiency, for instance, could yield nearly $3 per share (Walley and Whitehead (1994)).

Merger Activity

- In the first 9 months of 2007, according to Thomson Financial, worldwide merger activity hit $3.6 trillion, surpassing the total from all of 2006 combined (Wong (2007)).
- Successful mergers can add tremendous value; however, the failure rate is estimated to be between 74% and 83% (Devero (2004)).
- It is worthwhile to develop tools to better predict the associated strategic gains, which include, among others, cost savings (Eccles, Lanes, and Wilson (1999)).
- A successful merger depends on the ability to measure the anticipated synergy of the proposed merger (cf. Chang (1988)).

Motivation

- Developing Countries and the Environment
  - There is enormous potential for developing countries to adopt cleaner production, given current technologies as well as the levels of private capital investments.
  - For example, between 1988-1995, multinational corporations invested nearly $422 billion worth of new factories, supplies, and equipment in these countries (World Resources Institute (1998)).
  - Through globalization, firms of industrialized nations can acquire those firms in developing nations that offer lower production costs; however, more than not, combined with inferior environmental concerns.
  - The actions taken today will greatly influence the future scale of environmental and health problems.

Relevant Literature

- Farrell and Shapiro (1990), Spector (2003), Farrel and Shapiro (2001), Soylu et al. (2006), Xu (2007)).
- Nagurney (2008) developed a system optimization perspective for supply chain network integration in the case of horizontal mergers.
- According to Stanwick and Stanwick (2002), if environmental issues are ignored the value of the proposed merger can be greatly compromised.
- Lambertini and Mantovani (2007) conclude that horizontal mergers can contribute to reduce negative externalities related to the environment.

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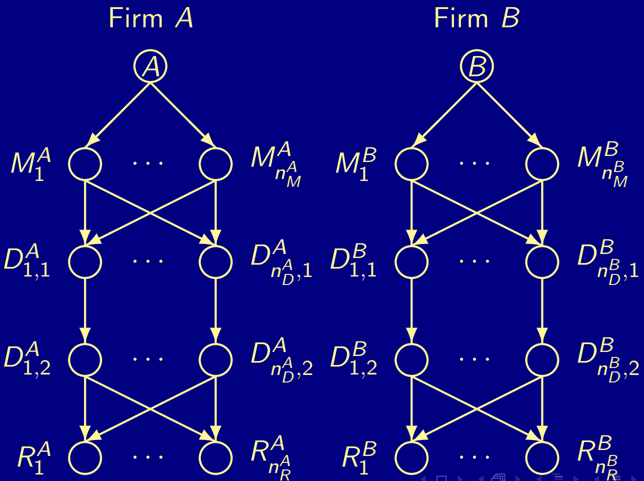
Supply Chains of Firms A and B Prior to the Merger: Case 0



The Pre-merger Multicriteria Decision-making Optimization Problem (Case 0)

The following conservation of flow equations must hold for each firm i:

$$\sum_{p \in P^0_{R^i_k}} x_p = d_{R^i_k}, \quad i = A, B; k = 1, \ldots, n^i_R,$$

where $P^0_{R^i_k}$ denotes the set of paths connecting (origin) node i with (destination) retail node R^i_k.

One must also have the following conservation of flow equations satisfied:

$$f_a = \sum_{p \in P^0} x_p \delta_{ap}, \quad \forall a \in L^0,$$

where P^0 denotes the set of *all* paths, that is, $P^0 = \cup_{i=A,B;k=1,\ldots,n^i_R} P^0_{R^i_k}$.

The Pre-merger Multicriteria Decision-making Optimization Problem (Case 0)

The path flows must be nonnegative, that is,

$$x_p \geq 0, \quad \forall p \in P^0.$$

The total cost on a link is assumed to be a function of the flow of the product on the link:

$$\hat{c}_a = \hat{c}_a(f_a), \quad \forall a \in L^0.$$

Assume given emission functions are assumed to be a function of the flow of the product on the link:

$$e_a = e_a(f_a), \quad \forall a \in L^0.$$

Assume that the costs are convex, continuously differentiable, and have a bounded second order partial derivative.

The Pre-merger Multicriteria Decision-making Optimization Problem (Case 0)

The individual cost minimization problems can be formulated jointly as follows:

$$\text{Minimize} \quad \sum_{a \in L^0} \hat{c}_a(f_a).$$

The individual emission minimization problems can be formulated jointly as follows:

$$\text{Minimize} \quad \sum_{a \in L^0} e_a(f_a).$$

A nonnegative constant, α_{ia}, is now assigned to the emissions-generation criterion for firms $i = A, B$ and links $a \in L_i$. For simplicity, $\alpha_{ia} \equiv 0$ if link $a \notin L_i$ and $\alpha_{ia} = \alpha_i$. α_{ia} can be assumed the price that each firm, i, would be willing to pay for each unit of emission. Thus, α_i, represents the weight of the environmental concern for each firm, i, and a higher α_{ia} represents a greater concern for the environment.

The Pre-merger Multicriteria Decision-making Optimization Problem (Case 0)

Consequently, the multicriteria decision-making problem, pre-merger, can be expressed as:

$$\text{Minimize} \quad \sum_{a \in L^0} \sum_{i=A,B} \hat{c}_a(f_a) + \alpha_{ia} e_a(f_a)$$

subject to the constraints presented earlier and

$$f_a \leq u_a, \quad \forall a \in L^0.$$

Observe that this problem is, as is well-known in the transportation literature (cf. Beckmann, McGuire, and Winsten (1956), Dafermos and Sparrow (1969)), a *system-optimization* problem but in *capacitated* form and with multicriteria decision-making; see also Patriksson (1994), Nagurney (2000, 2006b), and the references therein.

The Pre-merger Multicriteria Decision-making Optimization Problem (Case 0)

Under the imposed assumptions, the optimization problem is a convex optimization problem. If we further assume that the feasible set underlying the problem represented by the constraints is non-empty, then it follows from the standard theory of nonlinear programming (cf. Bazaraa, Sherali, and Shetty (1993)) that an optimal solution exists.

Also, associate the Lagrange multiplier β_a with constraint

$$f_a \leq u_a, \quad \forall a \in L^0$$

for link a and denote the associated optimal Lagrange multiplier by β_a^*. This term may also be interpreted as the price or value of an additional unit of capacity on link a.

The Variational Inequality Formulation of the Pre-Merger System-Optimized Problem

Theorem

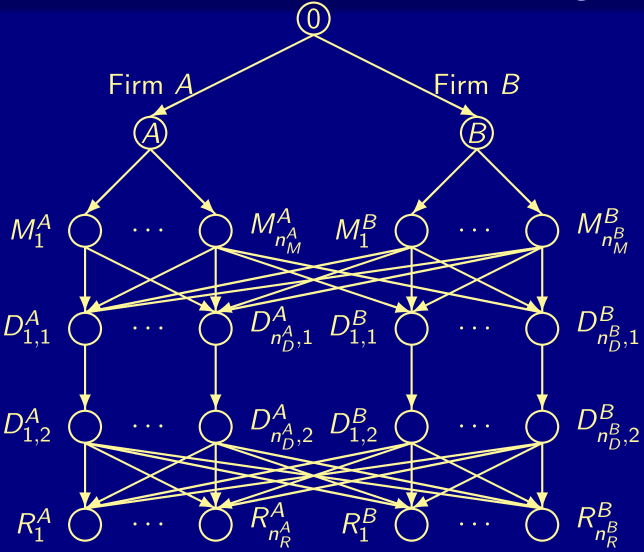
The vector of link flows $f^{*0} \in \mathcal{K}^0$ is an optimal solution to the pre-merger problem if and only if it satisfies the following variational inequality problem with the vector of nonnegative Lagrange multipliers β^{*0}:

$$\sum_{a \in L^0} \sum_{i=A,B} [\frac{\partial \hat{c}_a(f_a^*)}{\partial f_a} + \alpha_{ia} \frac{\partial e_a(f_a^*)}{\partial f_a} + \beta_a^*] \times [f_a - f_a^*]$$

$$+ \sum_{a \in L^0} [u_a - f_a^*] \times [\beta_a - \beta_a^*] \geq 0$$

$$\forall f \in \mathcal{K}^0, \forall \beta_a \geq 0, \forall a \in L^0.$$

Supply Chain Network after Firms A and B Merge: Case 1



The Post-merger Multicriteria Decision-making Optimization Problem (Case 1)

Refer to the network underlying this merger as $\mathcal{G}^1 = [N^1, L^1]$. L^1 represents all links in the post-merger network belonging to firm A and to firm B.

Associate total cost functions and emission functions with the new links and assume, for simplicity, that the corresponding functions on the links emanating from the supersource node are equal to zero.

A path p now originates at the node 0 and is destined for one of the bottom retail nodes.

Due to the merger, the retail outlets can obtain the product from any manufacturing plant and any distributor. The set of paths $P^1 \equiv \cup_{i=A,B;k=1,\dots,n^i_R} P^1_{R^i_k}$.

The Post-merger Multicriteria Decision-making Optimization Problem (Case 1)

Let x_p now in the post-merger network configuration denote the flow of the product on path p joining (origin) node 0 with a (destination) retailer node.

The following conservation of flow equations must hold:

$$\sum_{p \in P^1_{R^i_k}} x_p = d_{R^i_k}, \quad i = A, B; k = 1, \dots, n^i_R,$$

where $P^1_{R^i_k}$ denotes the set of paths connecting node 0 with retail node R^i_k.

One must also have the following conservation of flow equations satisfied:

$$f_a = \sum_{p \in P^1} x_p \delta_{ap}, \quad \forall a \in L^1.$$

The Post-merger Multicriteria Decision-making Optimization Problem (Case 1)

The path flows must be nonnegative, that is,

$$x_p \geq 0, \quad \forall p \in P^1.$$

Assume, again, that

$$f_a \leq u_a, \quad \forall a \in L^1.$$

The firms, pre-merger, assigned a weight representing their individual environmental concerns; post-merger, the weight was uniform, non-negative, denoted by α, representing a single decision-making economic entity.

The post-merger optimization problem is concerned with total cost minimization as well as the minimization of emissions.

The Post-merger Multicriteria Decision-making Optimization Problem (Case 1)

The following multicriteria decision-making optimization problem must now be solved:

$$\text{Minimize} \quad \sum_{a \in L^1} [\hat{c}_a(f_a) + \alpha e_a(f_a)]$$

subject to the constraints described earlier.

α can be assumed the price that the firm would be willing to pay for each unit of emission. Thus, α, represents the weight of environmental concern; and a higher α represents a greater concern for the environment.

There are distinct options for the weight α and we explore several in concrete numerical examples:

- Specifically, in the case that the merger is amicable, with α being a function of the firms' pre-merger weights.
- In the case that the merger is hostile, with the value of α being that of the dominant firm in the merger.

The Variational Inequality Formulation of the Post-Merger System-Optimized Problem

Theorem

The vector of link flows $f^{*1} \in \mathcal{K}^1$ is an optimal solution to the post-merger problem if and only if it satisfies the following variational inequality problem with the vector of nonnegative Lagrange multipliers β^{*1}:

$$\sum_{a \in L^1} [\frac{\partial \hat{c}_a(f_a^*)}{\partial f_a} + \alpha \frac{\partial e_a(f_a^*)}{\partial f_a} + \beta_a^*] \times [f_a - f_a^*] + \sum_{a \in L^1} [u_a - f_a^*] \times [\beta_a - \beta_a^*] \geq 0,$$

$$\forall f \in \mathcal{K}^1, \forall \beta_a \geq 0, \forall a \in L^1.$$

Quantifying Synergy Associated with Multicriteria Decision-Making Firms with Environmental Concerns in Mergers/Acquisitions

- Define the total generalized cost TGC^0 associated with the pre-merger problem, or Case 0 as the value of the pre-merger objective function evaluated at its optimal solution f^{*0}.

- Define the total generalized cost TGC^1 associated with the post-merger problem, or Case 1, as the value of the post-merger objective function evaluated at its optimal solution f^{*1}.

- These flow vectors are obtained from the solutions of the variational inequalities for the pre and post merger cases, respectively.

Quantifying Synergy Associated with Multicriteria Decision-Making Firms with Environmental Concerns in Mergers/Acquisitions

The synergy associated with the total generalized costs which captures both the total costs and the weighted total emissions is denoted by $\mathcal{S}^{TGC}$ and is defined as follows:

$$\mathcal{S}^{TGC} \equiv [\frac{TGC^0 - TGC^1}{TGC^0}] \times 100\%.$$

Quantifying Synergy Associated with Multicriteria Decision-Making Firms with Environmental Concerns in Mergers/Acquisitions

- Define TC^0 as the total costs generated under solution f^{*0}.
- Define TC^1 as the total costs generated under solution f^{*1}.

One can also measure the synergy by analyzing the total costs pre and post the merger (cf. Eccles, Lanes, and Wilson (1999) and Nagurney (2008)):

$$\mathcal{S}^{TC} \equiv [\frac{TC^0 - TC^1}{TC^0}] \times 100\%.$$

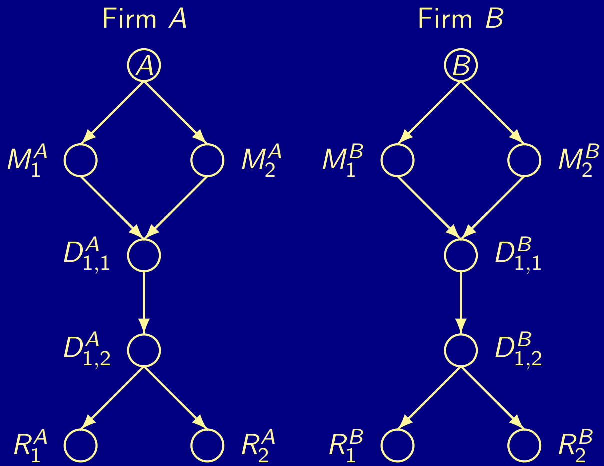
Quantifying Synergy Associated with Multicriteria Decision-Making Firms with Environmental Concerns in Mergers/Acquisitions

- Define TE^0 as the total emissions generated under solution f^{*0}.
- Define TE^1 as the total emissions generated under solution f^{*1}.

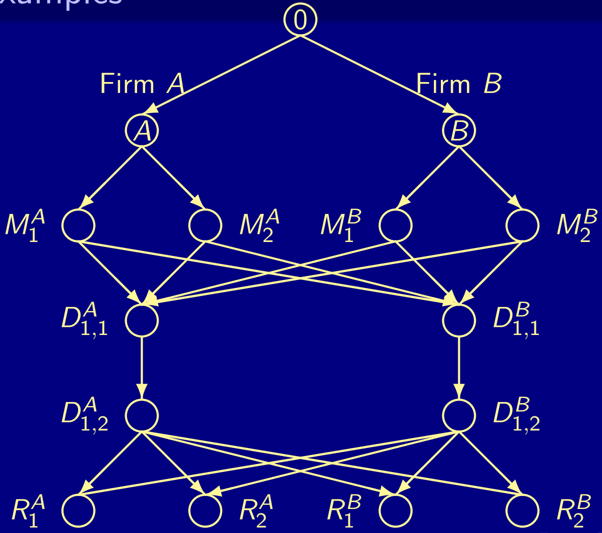
The total emissions synergy, denoted by $\mathcal{S}^{TE}$ is denoted as:

$$\mathcal{S}^{TE} \equiv [\frac{TE^0 - TE^1}{TE^0}] \times 100\%.$$

Pre-Merger Supply Chain Network Topology for the Numerical Examples



Post-Merger Supply Chain Network Topology for the Numerical Examples



Numerical Example 1

The total cost functions were: $\hat{c}_a(f_a) = f_a^2 + 2f_a$ for all links a pre-merger and post-merger in all the numerical examples, except for the links post-merger that join the node 0 with nodes A and B, which had associated total costs equal to 0.

The total emission functions were: $e_a(f_a) = 10f_a$ for all links a pre-merger and post-merger, except for the links post-merger that join the node 0 with nodes A and B, which had associated total costs equal to 0.

The weights: $\alpha_{ia} = \alpha_i$ were set to 1 for both firms $i = A, B$ and for all links $a \in L^0$.

The capacity on each link was set to 15 both pre and post merger.

The weight α, post-merger, was set to 1.

Numerical Examples

Numerical Example 2

- Pre and post-merger, the emission functions of firm A were reduced from $e_a(f_a) = 10f_a$ to $e_a(f_a) = 5f_a$, $\forall a \in L^0, L^1$.
- Pre-merger, the environmental concern of firm B was reduced to zero, that is, $\alpha_{Ba} = 0$, for all links a associated with firm B.
- One can assume an amicable merger, thus, post-merger, $\alpha = 0.5$.
- In the event of an amicable merger between firms that have different environmental concerns & activities to reduce emissions, there was an increase in emission synergy.
- There was a tradeoff between operational synergy gains with environmental benefits. The total generalized cost synergy decreased even more drastically than the environmental gains which signifies the influential effect environmental concerns had on the objective of the firm *pre* & *post* merger.

Numerical Examples

Numerical Example 3

- Ex. 3 was constructed from Ex. 2 but now assumed that the merger was hostile, but with firm B as the dominant firm, hence, $\alpha = 0$.
- In the event of a hostile merger with the dominant firm not environmentally conscious, the total generalized cost was the highest at 34.88%.

Numerical Example 4

- Ex. 4 was constructed from Ex. 1 but, pre-merger, firm B does not display any concern for the environment, that is, $\alpha_{Ba} = 0$ for all its links.
- Additionally, it was now assumed that the merger was hostile with firm A as the dominant firm, hence, post-merger, $\alpha = 1$.
- In the event of a hostile merger with the dominant firm being environmentally conscious, the total generalized cost was the lowest at -28.30%.

Synergy Values for the Numerical Examples

Example	1	2	3	4
TC^0	660.00	660.00	660.00	660.00
TC^1	560.00	565.65	560.00	560.00
S^{TC}	15.15%	14.30%	15.15%	15.15%
TE^0	800.00	600.00	600.00	800.00
TE^1	800.00	574.63	600.00	800.00
S^{TE}	0.00%	4.23%	0.00%	0.00%
TGC^0	1460.00	860.00	860.00	1060.00
TGC^1	1360.00	852.97	560.00	1360.00
S^{TGC}	6.85%	0.82%	34.88%	−28.30%

Additional Examples

In addition, we explored the impacts of improved technologies associated with distribution/transportation.

The data were as in Examples 1 through 4 except that we assume now that the emission functions associated with the new "merger" links were all identically equal to 0.

The synergies computed for this variant of Examples 1 through 4 suggest an inverse relationship between total cost synergy and emission synergy.

Synergy Values for the Variant Numerical Examples

Example	1	2	3	4
TC^0	660.00	660.00	660.00	660.00
TC^1	660.00	577.89	560.00	660.00
S^{TC}	0.00%	12.44%	15.15%	0.00%
TE^0	800.00	600.00	600.00	800.00
TE^1	400.00	375.75	450.00	400.00
S^{TE}	50.00%	37.38%	25.00%	50.00%
TGC^0	1460.00	860.00	860.00	1060.00
TGC^1	1060.00	765.77	560.00	1060.00
S^{TGC}	27.40%	10.96%	34.88%	0.00%

Conclusions

- We presented a multicriteria decision-making framework to evaluate the environmental impacts associated with mergers and acquisitions.
- The framework is based on a supply chain network perspective, in a system-optimization context, that captures the economic activities of a firm such as manufacturing/production, storage, as well as distribution.
- We presented the pre-merger and the post-merger network models, derived their variational inequality formulations, and then defined a total generalized cost synergy measure as well as a total cost synergy measure and a total emissions synergy measure.
- The firms, pre-merger, assigned a weight representing their individual environmental concerns; post-merger, the weight was uniform.

Conclusions

- The numerical examples, although stylized, demonstrated the generality of the approach and how the new framework can be used to assess apriori synergy associated with mergers and acquisitions and with an environmental focus.
- The operating economies (resulting from greater economies of scale that improve productivity or cut costs) may have an inverse impact on the environmental effects to society depending on the level of concern that each firm has for the environment and their joint actions taken to reduce emissions.

Conclusions

- To the best of our knowledge, this is the first paper to quantify the relationships associated with mergers and acquisitions and possible synergies associated with environmental emissions.
- With this paper, we can begin to further explore numerous questions associated with mergers and acquisitions, environmental synergies, as well as industrial organization.

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Thank you!

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